

DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improved Aerodynamics

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Overview

Timeline

Demonstrated a breakthrough in aerodynamic performance of heavy vehicles

- Designed an integrated tractor-trailer geometry called Generic Speed Form (GSF1 and GSF2)
- Performed wind tunnel tests of GSF geometry and selected aero devices for tractor-trailers and tankers to improve fuel efficiency

Budget

- Funding for FY15, \$850K
- Funding for FY16, \$1000K

Barriers

- Reduce aerodynamic drag of class 8 tractor-trailers by approximately 25% leading to a 10-15% increase in fuel efficiency at 65 mph

Partners

- *Navistar, Inc.*
- *Kentucky Trailer and Wabash National*
- *Freight Wing Inc. and ATDynamics*
- *Frito-Lay, Spirit, and Safeway*
- *Michelin*
- *Praxair*
- *NREL*
- *NASA, Army, and Air Force*



Class 7-8 tractor-trailers are responsible for 12% of the total US consumption of petroleum

2.5 million combination trucks¹

66,161 average miles/year/vehicle

5.8 average miles/gallon

Aerodynamic drag reduction contribution

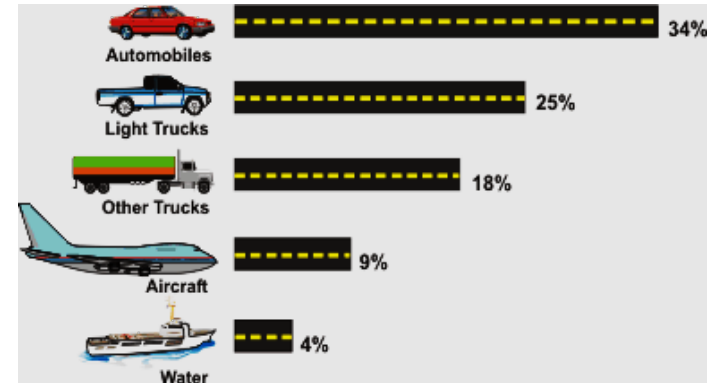
15% reduction in fuel use = 4.2 billion gallons of diesel fuel saved per year and 42 million tons of CO₂ emission

\$8.9 billion saved/year (\$2.11 per gallon diesel)

Tractor-Trailer integration (GSF) radically decreases aerodynamic drag

Up to 40% reduction in fuel use

Wide-base single tires add about 4-5% to overall vehicle fuel economy



1. U.S. Department of Energy, Transportation Energy Data Book, Edition 32, July 2014

Tanker trailers are responsible for 1.3% of the total US consumption of petroleum

Approximately 200,000 tanker trailers¹
60,000 average miles/year/vehicle
4.5 average miles/gallon

Aerodynamic drag reduction contribution

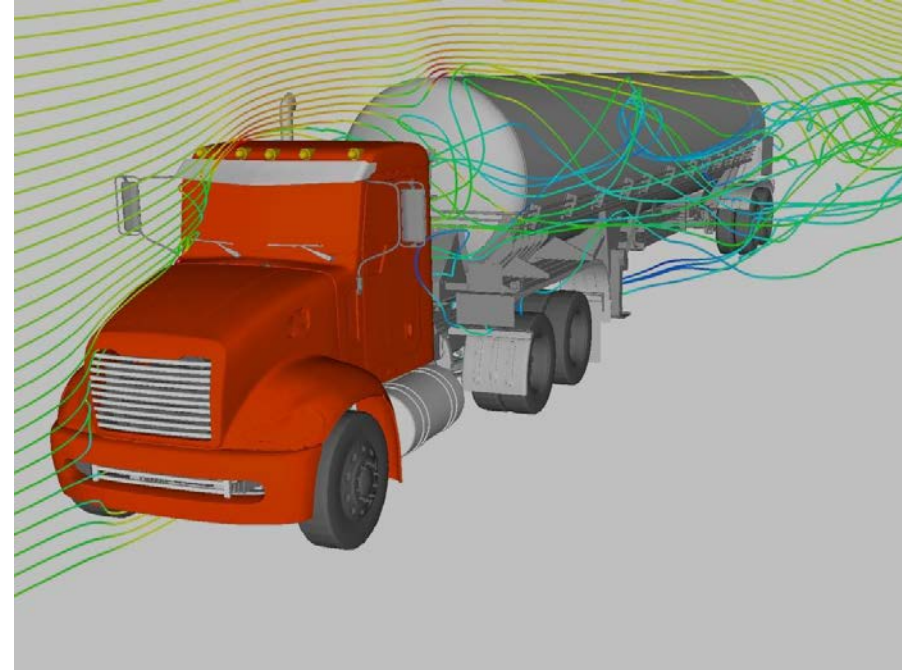
17% reduction in fuel use = 0.6 billion gallons of diesel fuel saved per year and 6 million tons of CO₂ emission

\$1.3 billion saved/year (\$2.11 per gallon diesel)

Tractor-Trailer integration radically decreases aerodynamic drag

Up to 40% reduction in fuel use

Wide-base single tires add about 4-5% to overall vehicle fuel economy



1. National Tank Truck Association, www.tanktruck.org

Objectives

- **In support of DOE's mission**, provide guidance to industry to improve the fuel efficiency of class 8 tractor-trailers and tankers through enhanced aerodynamics
- **Demonstrate** new aerodynamic body shapes, drag-reduction techniques, and concepts
 - Class 8 tractor-trailers and tankers
- **Develop the next generation of highly aerodynamic and integrated class 8 tractor-trailers and tankers**
- **Investigate the fuel economy benefits of truck platooning**
- **Joined with industry in promoting the new body shapes and getting aerodynamic devices on the road**
- **On behalf of DOE** to expand and coordinate industry participation to achieve significant on-the-road fuel economy improvement

Milestones

FY15

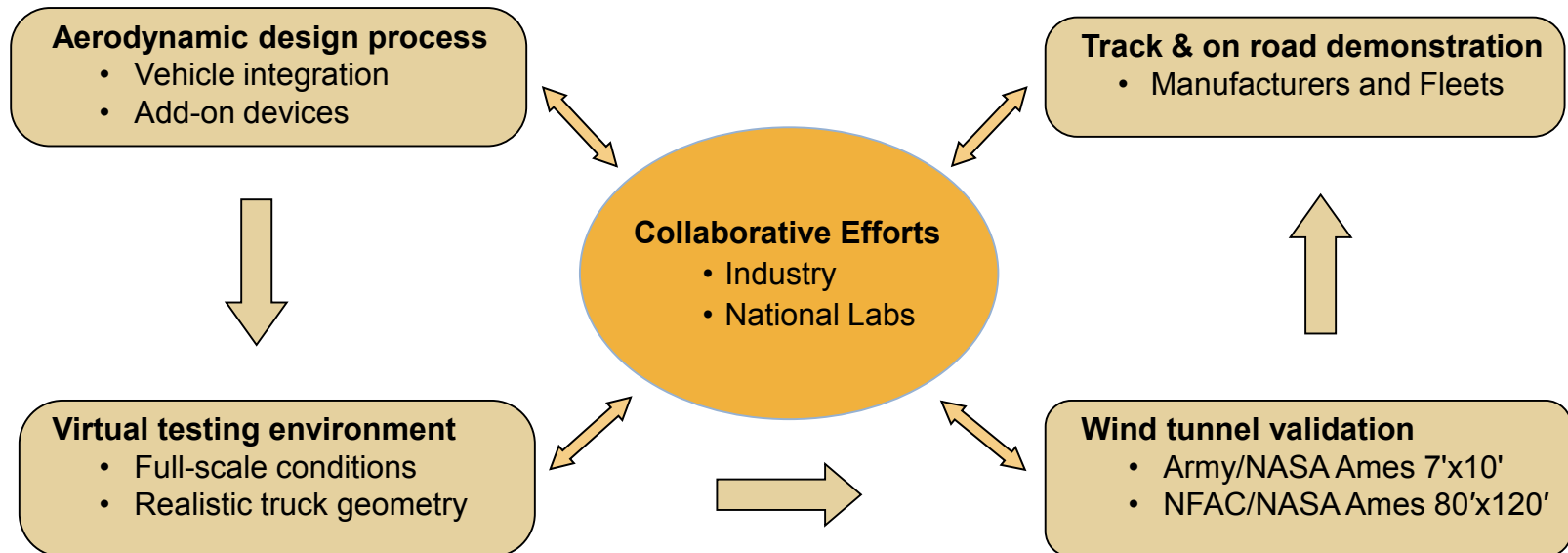
- **Started the design process of the first generation of a highly aerodynamic and integrated tractor-trailer geometry called Generic Speed Form 1 (GSF1)**
- Continue to improve the design/performance of selected aero devices
- Continue to improve the aerodynamics of tanker trailers
- Performed wind tunnel tests to validate the performance of aero devices and integrated design for tractor-trailers and tankers

FY16

- **Designed the second-generation of our Generic Speed Form call GSF2**
- **Analyzed wind tunnel test results for GSF2**
- **Analyzed wind tunnel test results on aerodynamically treated tanker-trailers**
- Continue to improve the design/performance of an integrated skirt and tail devices
- Investigated tractor-trailer underbody flow for drag reduction
- Investigated the performance of aero devices and integrated design for tractor-trailers and tankers

Science-based approach is used to develop an integrated highly aerodynamic heavy vehicles

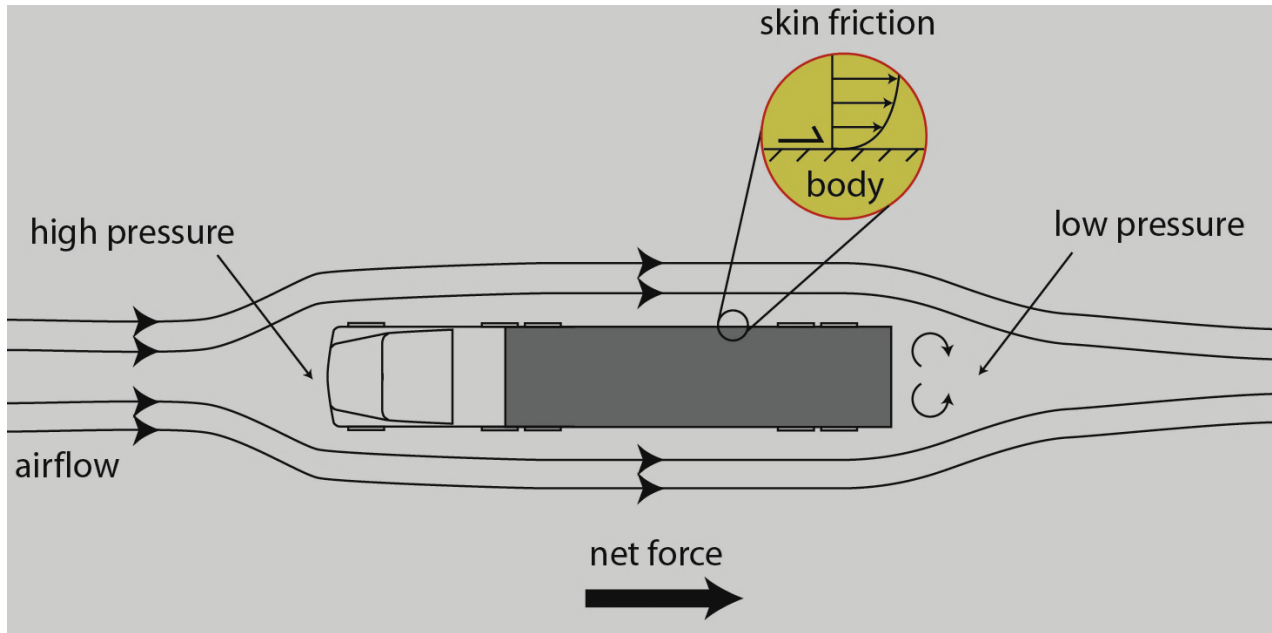
Validate aerodynamic body shapes and concepts with industry collaboration and feedback



Technical accomplishments

- **Designed the second generation** of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel economy (GSF2).
 - GSF2 tractor design was completed with the aid of wind tunnel testing
 - GSF2 represents a breakthrough in aerodynamic performance
- **Conducted 1/8 scale experiments** at the Army 7'x10' wind tunnel facility at Ames Research Center
- **Evaluated the aerodynamic performance** of integrated skirt and tail devices
 - Underbody flow investigation
- **Developed a new tanker-trailer model** for aerodynamic investigations
- **Improved aerodynamics of existing tanker-trailers** using add-on devices for significant gain in fuel economy
- **Achieved international recognition** through open documentation and conferences

Improved fuel economy is achieved through enhanced aerodynamics



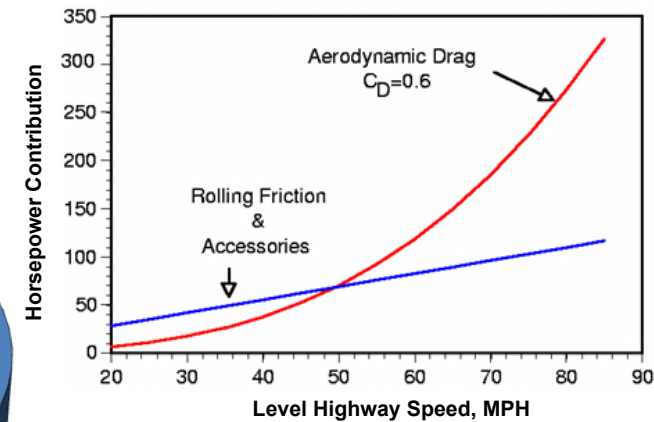
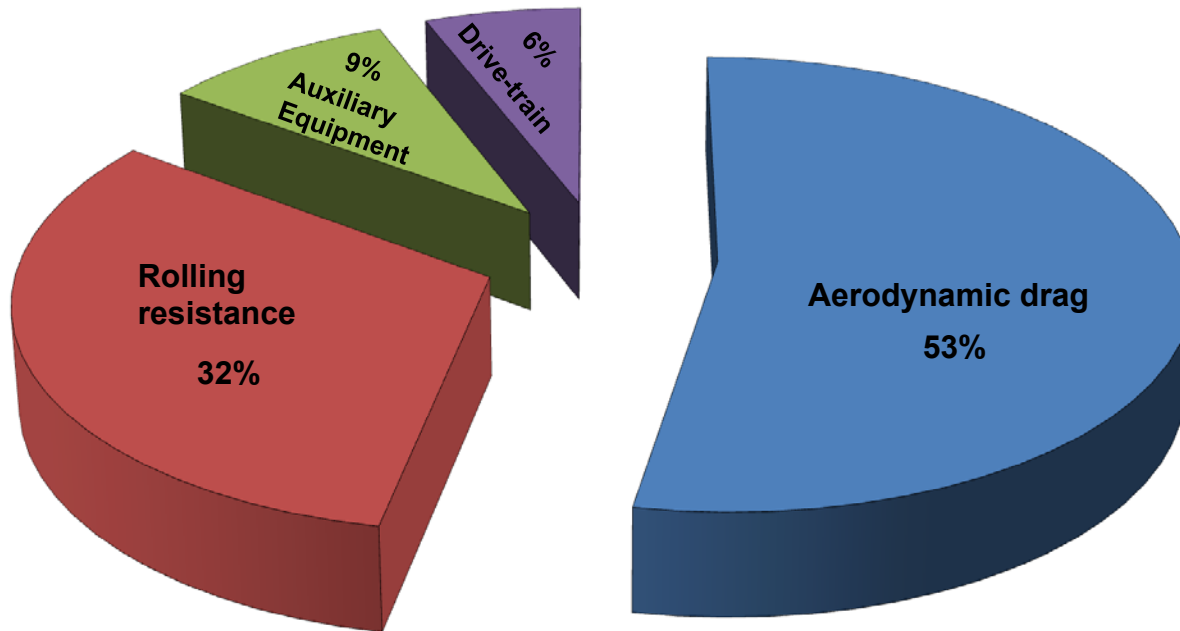
$$Drag = C_D \times S \times (1/2) \rho U^2$$

shape

cross-section

speed

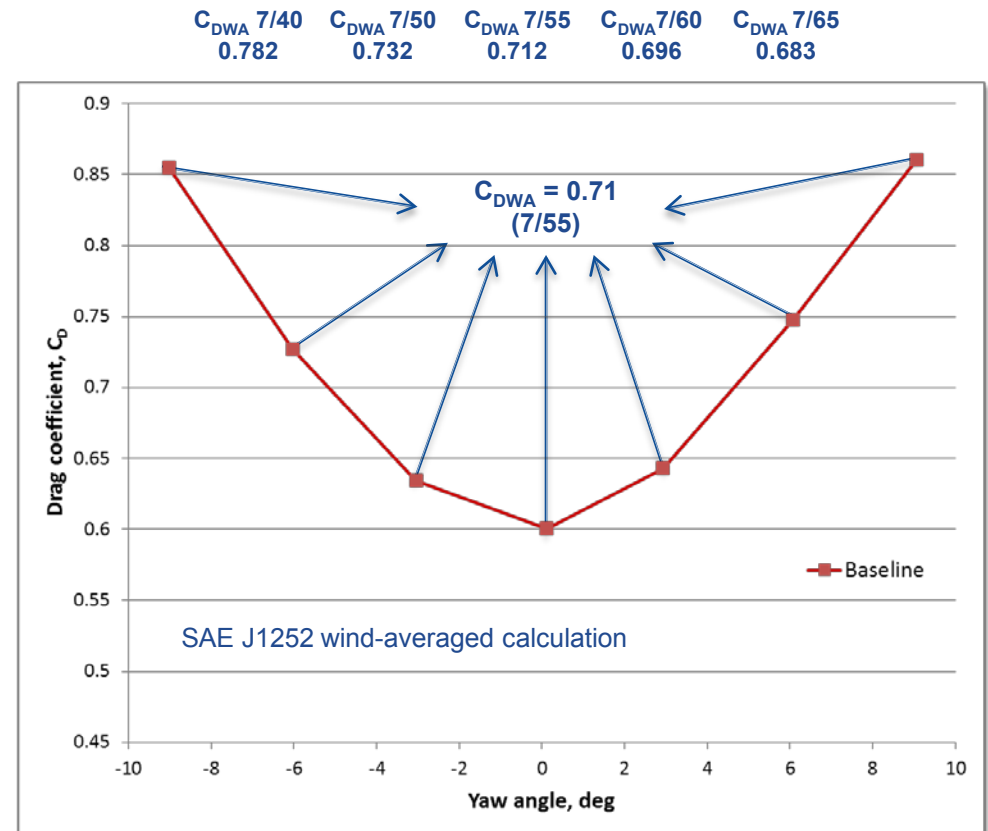
Heavy trucks use most of their usable propulsion energy to overcome drag and rolling resistance at highway speed



Wide-base single tires

Losses in nearly all of these categories can be reduced by employing presently available technology

How to represent an aerodynamic performance of a typical vehicle on the road

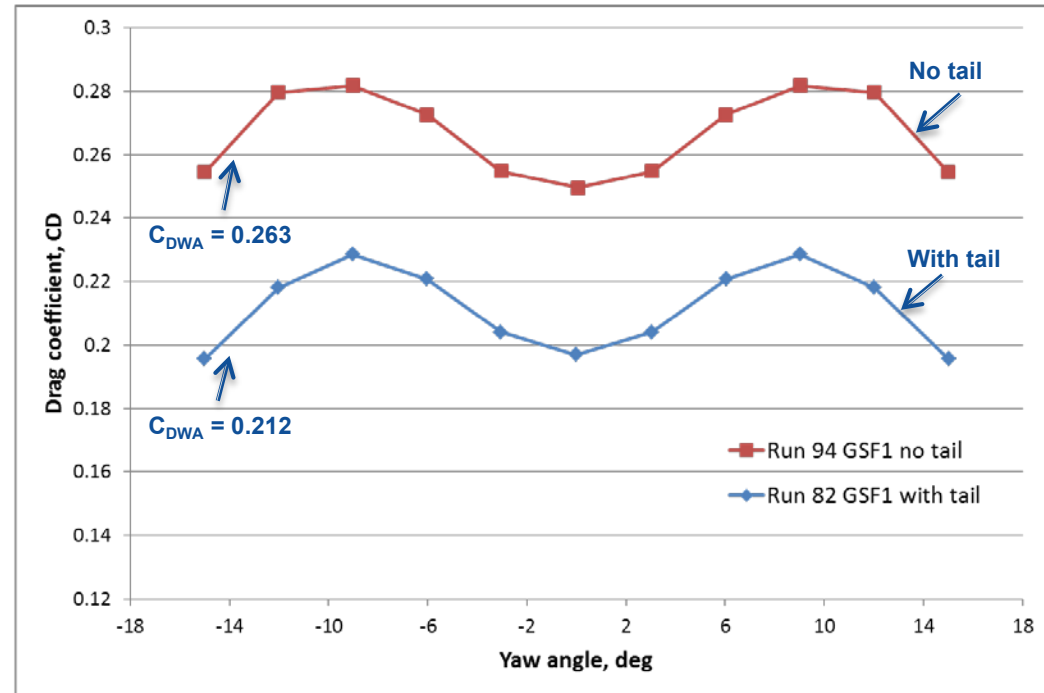


Drag = 93% pressure + 7% skin friction

Generic Speed Form 1 (GSF1) reveals an aerodynamic sailing effect



Designed in 2014



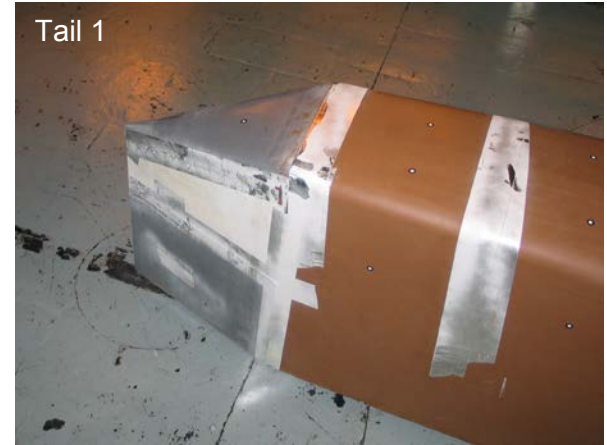
Drag = 64% pressure + 36% skin friction

GSF2 design shows a more enhanced sailing effect compared to GSF1

GSF2



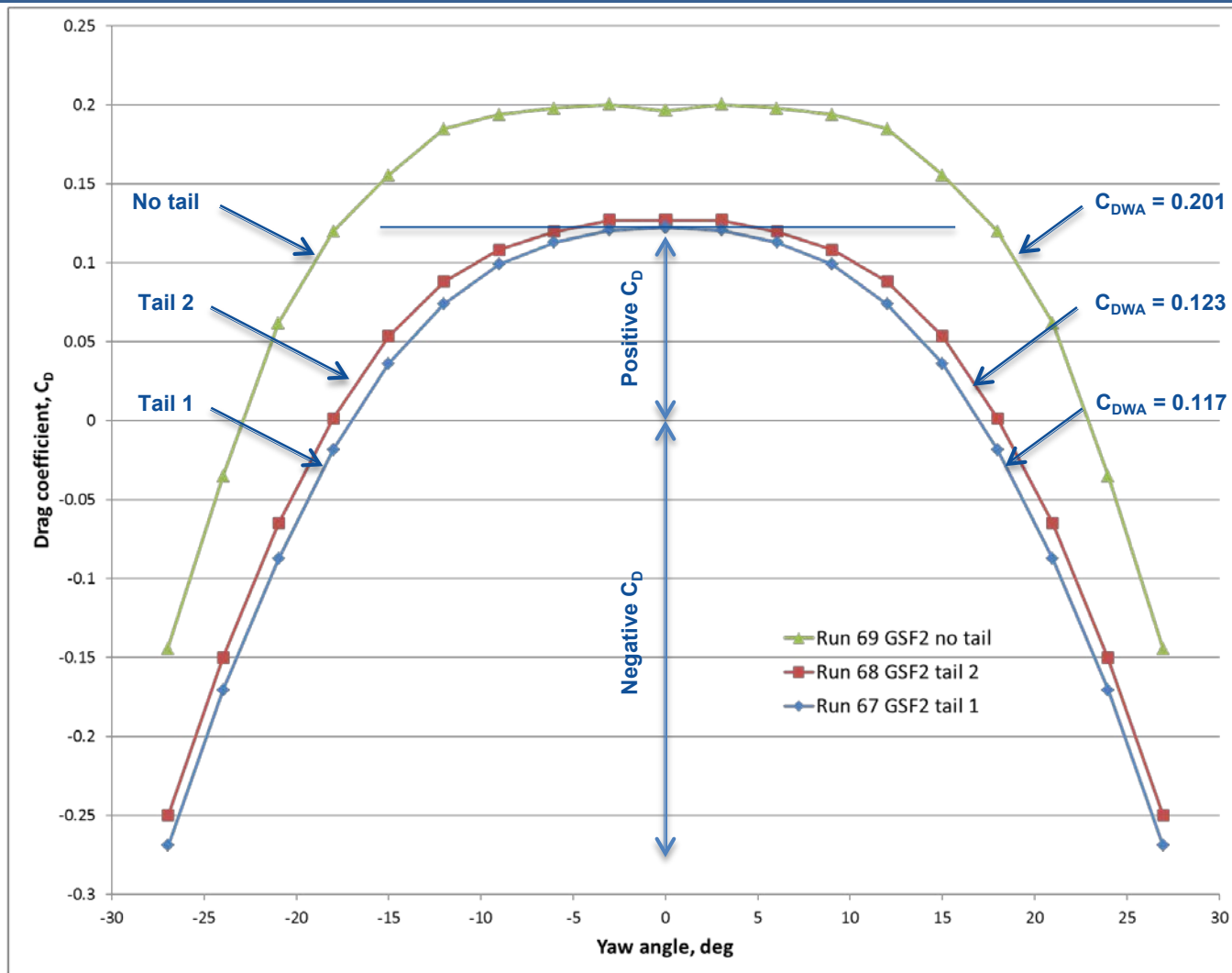
Tail 1



Tail 2

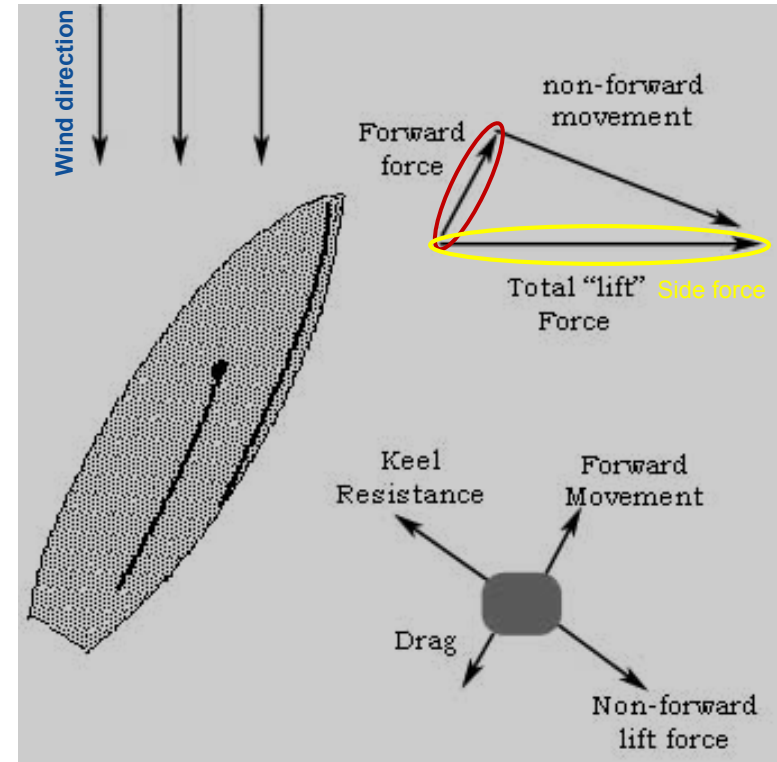


GSF2 aerodynamic performance is radically different from a typical heavy vehicle on the road

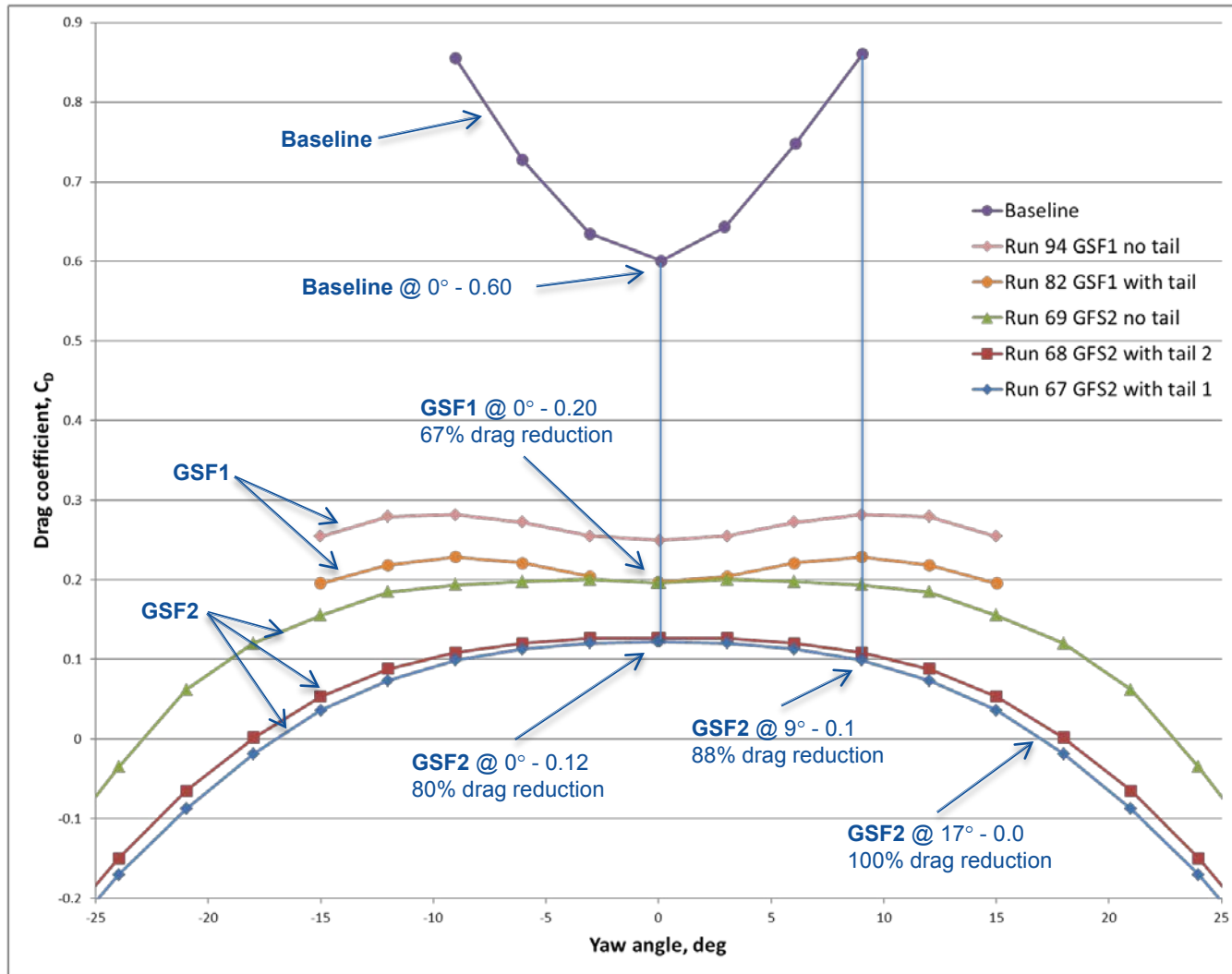


GSF2 can generate forward force at yaw due to the sailing effect

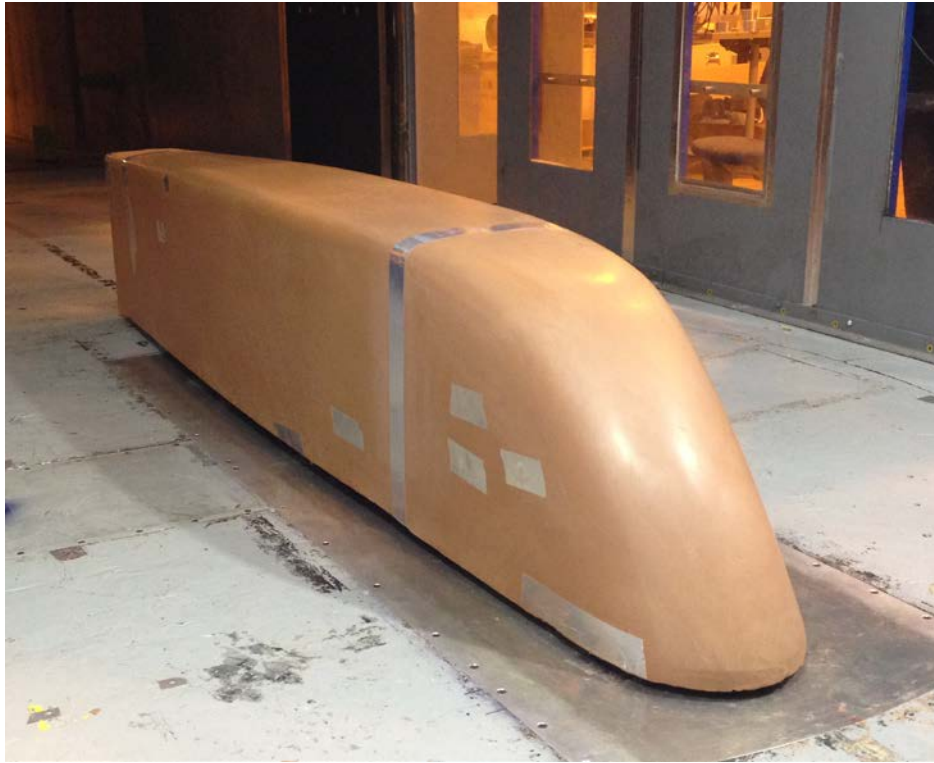
GSF2



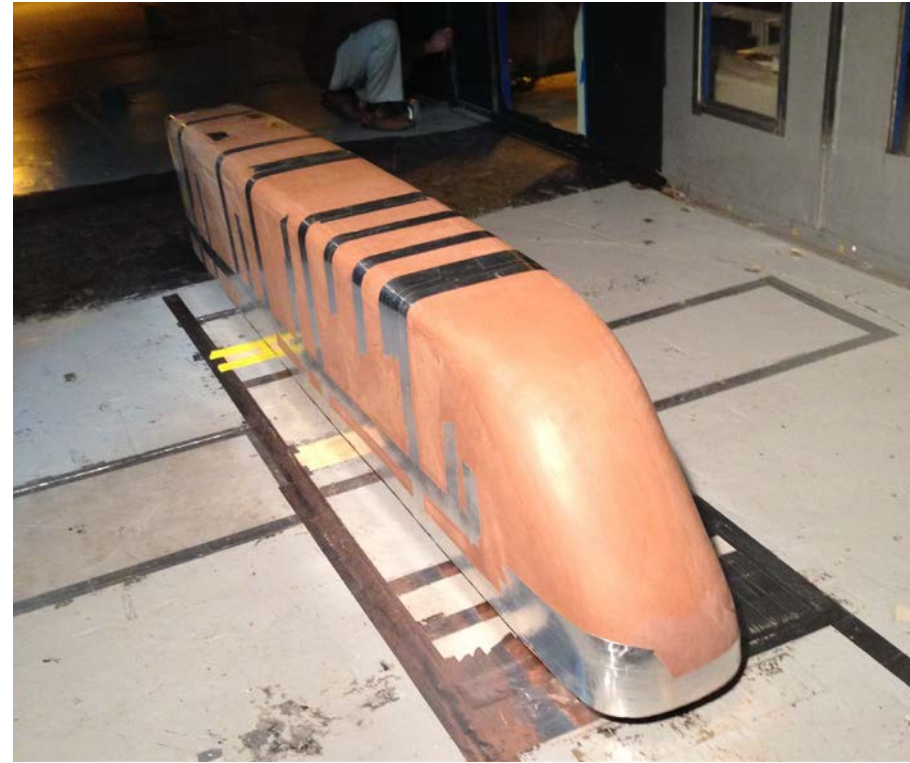
GSF2 demonstrates radical drag reduction



GSF2 has a more aggressive teardrop shape compared to GSF1

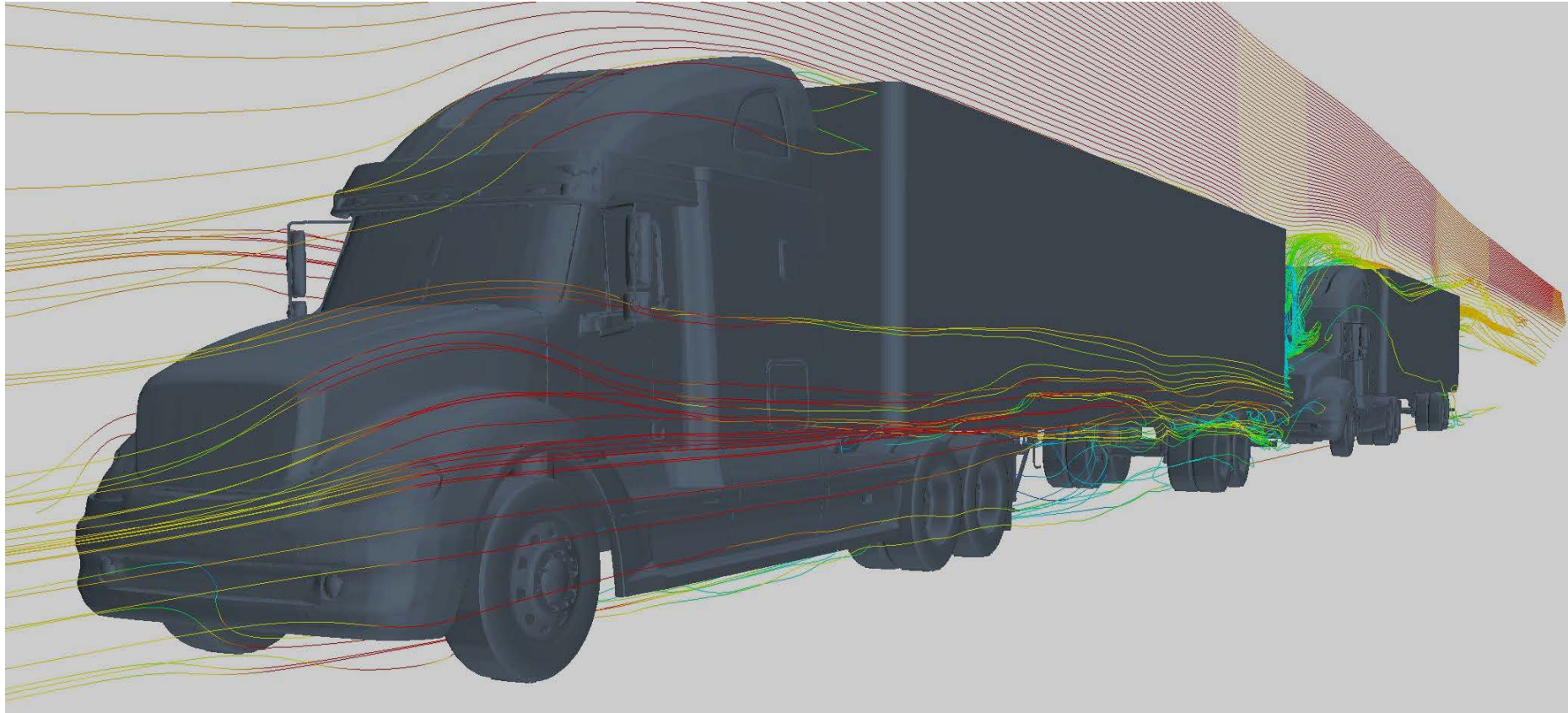


Generic Speed Form 2

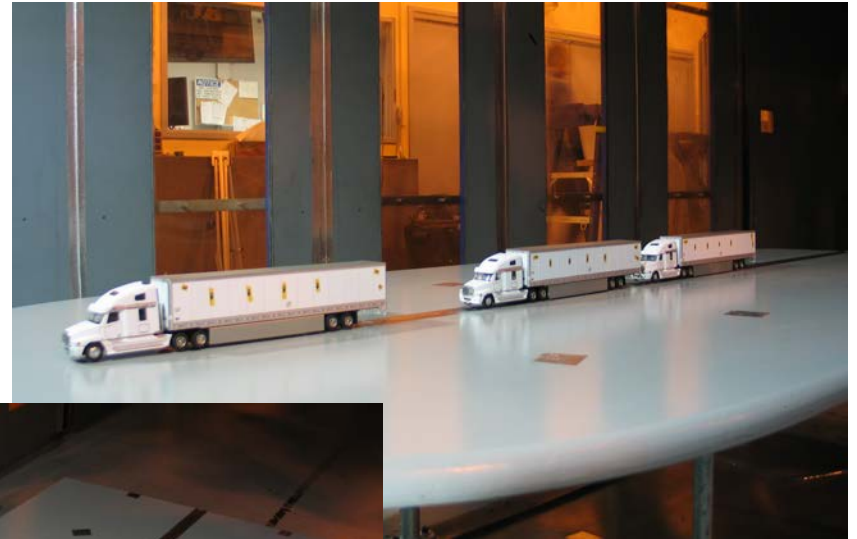


Generic Speed Form 1

We are working closely with NREL to investigate the fuel economy benefits of truck platooning



Vehicle platooning has shown aerodynamic benefits beyond what was expected

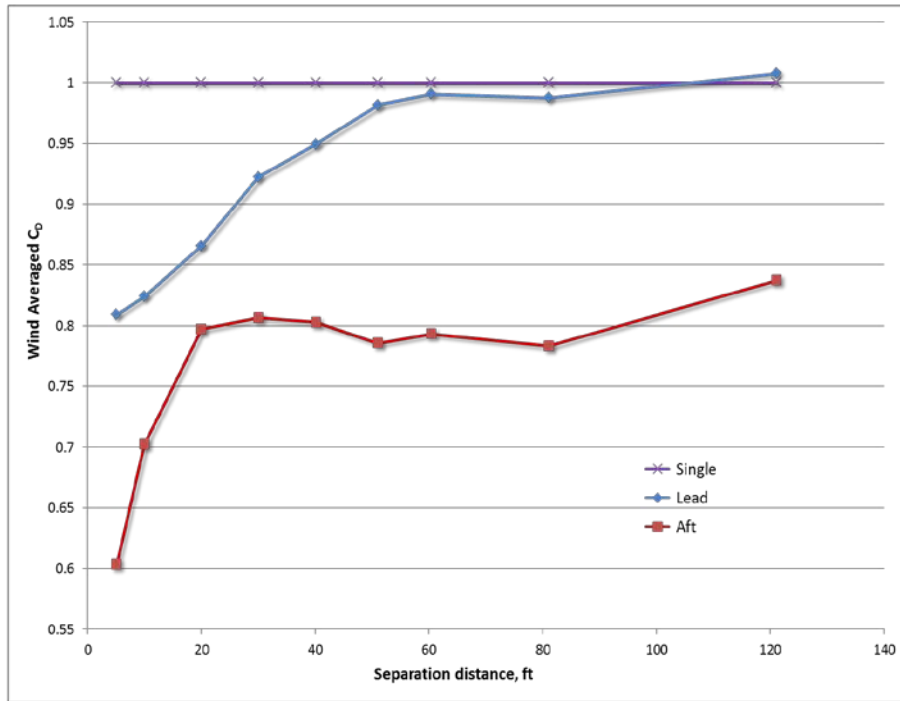


Body axis wind averaged drag measurements

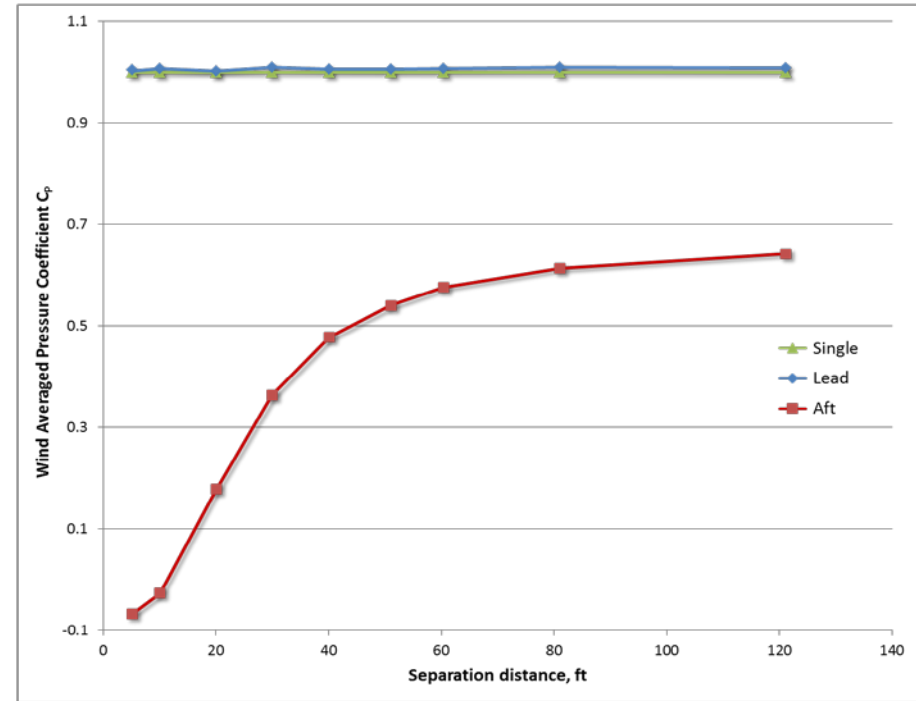


Army 7'x10' wind tunnel facility at NASA Ames Research Center

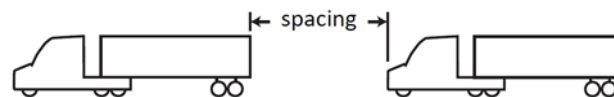
Two vehicle configuration, scaled wind tunnel results



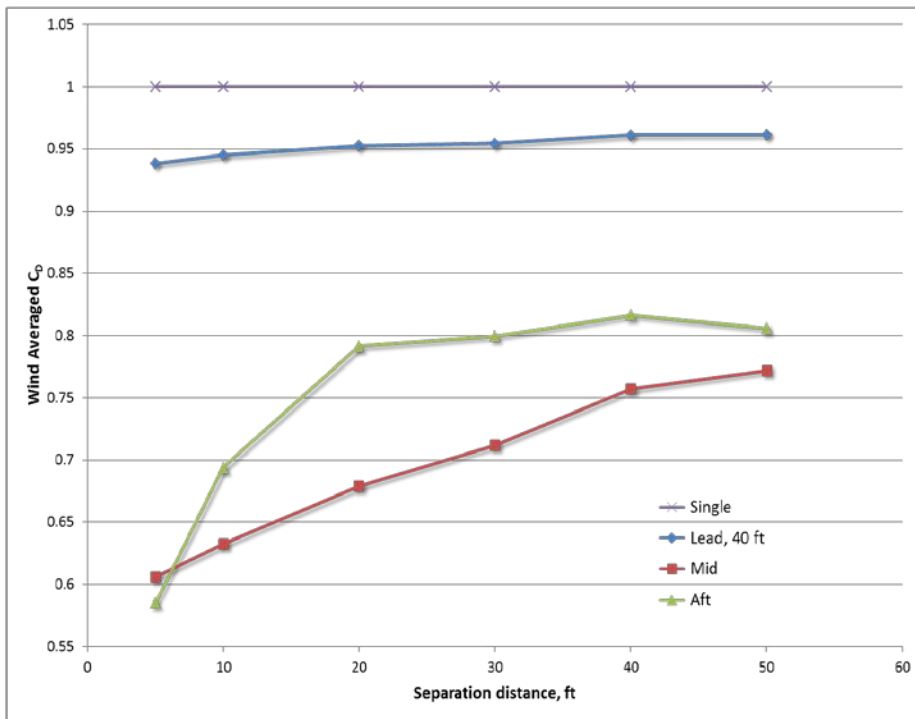
Aerodynamic benefits



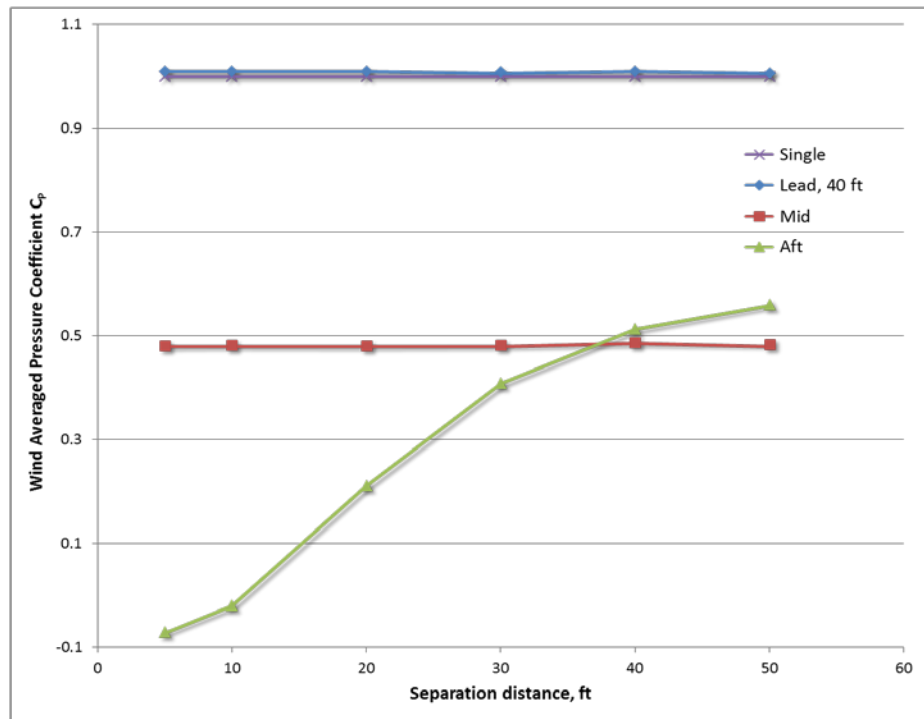
Engine cooling air supply



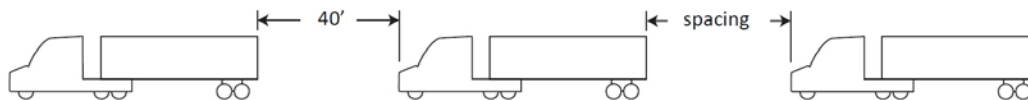
Three vehicle configuration – scaled wind tunnel results, 40'



Aerodynamic benefits



Engine cooling air supply



A new tanker trailer model was developed for aerodynamic wind tunnel testing



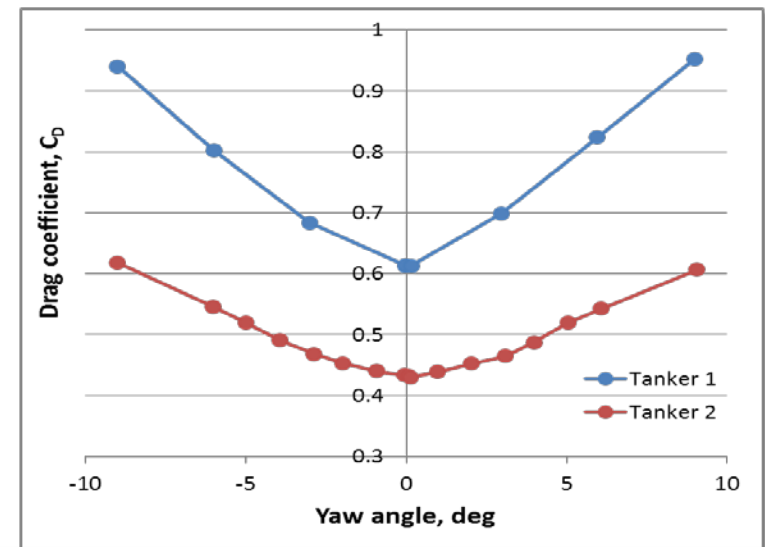
Tanker 1

- 60" tractor-trailer gap
- Elliptical tank cross-section



Tanker 2

- 72" tractor-trailer gap
- Circular tank cross-section



Responses to Previous Year Reviewers' Comments

Comment: Tractor trailer aero is a key lever for further fuel consumption reduction

Response: We completely agree, aerodynamic drag is a significant contributor to fuel consumption

Comment: This is a well established and solid approach by the project team, tested and proven over many years of research

Response: Our approach to innovate and push the state-of-the-art has worked well

Comment: Science based computational work is appropriate to explore the design space

Response: Without the aid of computational modeling and simulations our effort would not be possible

Comment: The integrated approach using the generic speed form (GSF) model, **despite practical implementation difficulties in the real world, is essential to show what is possible in truck aero drag reduction** (One key benefit of this work is demonstrating the aero drag reduction possibilities with new creative solutions)

Response: The LLNL Generic Speed Form geometries represent the state-of-the art in aerodynamic shape design for heavy vehicles that can easily be shared with all OEMs

Comment: **This project is not discussed in the industry as much as the reviewer would expect or desire**

Response: We are open to suggestions as how to improve the visibility of this research among industry

Comment: The emphasis on tanker trailers is questionable, given the relatively small population of tankers compared to dry van trailers

Response: Our aerodynamic tanker-trailer improvements is a natural extension of our tractor-trailer research and it does not require significant effort

Comment: **The reviewer strongly supports the efforts on trailer aerodynamics and platooning.** This can critically help the future of platooning, a rather simple, high fuel saving concept

Response: We agree, platooning provides a simple approach to fuel saving

Collaboration and Coordination with Other Institutions

- Navistar, Inc.
 - Tractor design and wind tunnel testing
- Wabash National and Kentucky Trailer
 - Trailer design
- Freight Wing Inc. and ATDynamics
 - Aerodynamic add-on devices
- Frito-Lay, Spirit, and Safeway
 - On the road testing of aerodynamic devices (multi-year data collection)
- Michelin
 - Lower rolling resistance wide-base single tires
- Praxair
 - Testing our tractor-tanker gap treatment idea
- NREL
 - Full-scale truck platooning track tests
- NASA, Army, Air Force
 - Wind tunnel testing from small-scale to full-scale

Future plans

- **Continue with tractor-trailer integration design for radical improvement in aerodynamic drag and fuel economy**
- **Continue with experiments to design the GSF3 integrated tractor-trailer**
- Continue to perform scaled experiments to design and validate the performance of aerodynamic add-on devices for an integrated tractor-trailers and tankers
- **Begin to design the next generation of highly aerodynamic tankers**
- Continue to work with tanker fleets to improve fuel economy
- Continue with the investigation of fuel economy benefits of truck platooning in collaboration with NREL
- On behalf of DOE, continue to coordinate industry participation to design the next generation of highly aerodynamic heavy vehicles

Summary

- **Designed the second generation of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel economy (GSF2)**
 - Breakthrough in vehicle aerodynamic performance
- Conducted 1/8 scale experiments at Army 7'x10' wind tunnel facility at the Ames Research Center
 - Tractor-trailers and tankers
 - Truck platooning, two and three vehicle configurations
- Analyzed wind tunnel experimental results for GSF2
- Analyzed wind tunnel results for new tanker
- Started to investigate the fuel economy benefits of truck platooning in collaboration with NREL for two to three vehicles
- Achieved major reduction in aerodynamic drag for tanker trailers through geometry modifications